

## LANDSCAPE AND FINE SCALE HABITAT ASSOCIATIONS OF THE LOGGERHEAD SHRIKE

HEIDI L. MICHAELS<sup>1</sup> AND JACK F. CULLY, JR.<sup>1,2</sup>

**ABSTRACT.**—This study was conducted to determine landscape and fine-scale vegetative variables associated with breeding Loggerhead Shrikes (*Lanius ludovicianus*) on Fort Riley Military Reservation, Kansas. Because Fort Riley is an Army training site, the influences of training disturbance to the vegetation, and range management practices on bird habitat patterns were also investigated. Breeding birds were surveyed in 1995 and 1996 using point counts. Survey plots were identified, *a priori*, at the landscape scale as either grassland, savannah, or woodland edge according to cover by woody vegetation. In 1996, fine-scale habitat at survey points and at bird use sites was measured and a principal components analysis used to characterize the fine-scale herbaceous vegetation structure. A military disturbance index was developed to quantify the severity of vehicle disturbance to the vegetation at survey and bird use sites. Shrikes were associated with savannah habitat at the landscape scale. Sites used by Loggerhead Shrikes were characterized at the fine-scale by tall, sparse, structurally heterogeneous herbaceous vegetation with high standing dead plant cover and low litter cover. At the fine-scale, tree and shrub density did not differ between sites used and not used by shrikes. Used sites did not differ from survey sites with respect to military training disturbance, hay harvest, or the number of years since a site was last burned. Our results in this study suggest that the shifting mosaic of vegetation on Fort Riley resulting from training and range management practices maintains adequate habitat for breeding shrikes. *Received 25 Sept. 1997, accepted 18 June 1998.*

Declines in numbers of Loggerhead Shrikes (*Lanius ludovicianus*) have been reported for most areas of the United States and for western Canada (Arbib 1976, 1977, 1978, 1979; Cade and Woods 1997; Kridelbaugh 1981; Morrison 1981; Telfer 1992). In Kansas, the Loggerhead Shrike is designated as a “Species in Need of Conservation” (Kansas Department of Wildlife and Parks 1986). While reasons for the continued decline of Loggerhead Shrike populations remain unclear, loss of breeding and/or wintering habitat is a probable cause (Kridelbaugh 1981, Smith and Kruse 1992).

Shrikes in the eastern U.S. are associated with pastures of relatively short vegetation that offer adequate foraging and perching sites such as utility wires or isolated trees (Bohall-Wood 1987, Brooks and Temple 1990, Smith and Kruse 1992, Telfer 1992, Yosef and Grubb 1993). Management recommendations resulting from these studies have been to provide short grassy habitat interspersed with scattered elevated perches. These recommendations may not be applicable to shrikes breeding in non-agricultural systems.

The structure of herbaceous vegetation in areas of extensive agriculture and grazing is relatively simple and homogenous. As a result, quantification of habitat in the above studies was restricted to percent cover of broad habitat types such as pastures or row-crops (Bohall-Wood 1987, Brooks and Temple 1990). Native grasslands exhibit greater structural heterogeneity, and shrikes breeding in these areas may reveal different or more complex habitat association patterns (Prescott and Collister 1993, Chavez-Ramirez et al. 1994). Native grassland may provide suitable and adequate perch sites for foraging shrikes in the absence of powerlines, fences, or other artificial perching substrates (Chavez-Ramirez et al. 1994).

The structure of herbaceous vegetation within a grassland may be very different depending on how often it is disturbed by burning, grazing, or, in the case of Fort Riley, by military vehicles. Unburned tallgrass prairie is structurally heterogeneous because of the interspersed standing dead vegetation, forbs, and woody vegetation. Cover and depth of residual litter can be quite high in unburned prairie. Annual fire in the absence of grazing tends to favor dense, homogenous cover by warm season grasses (Gibson 1989), but periodic early spring burns such as those implemented on Fort Riley eliminate litter and in-

<sup>1</sup> Kansas Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, Biological Resources Division, 204 Leasure Hall, Kansas State Univ., Manhattan, KS 66506.

<sup>2</sup> Corresponding author; E-mail: bcully@ksu.edu

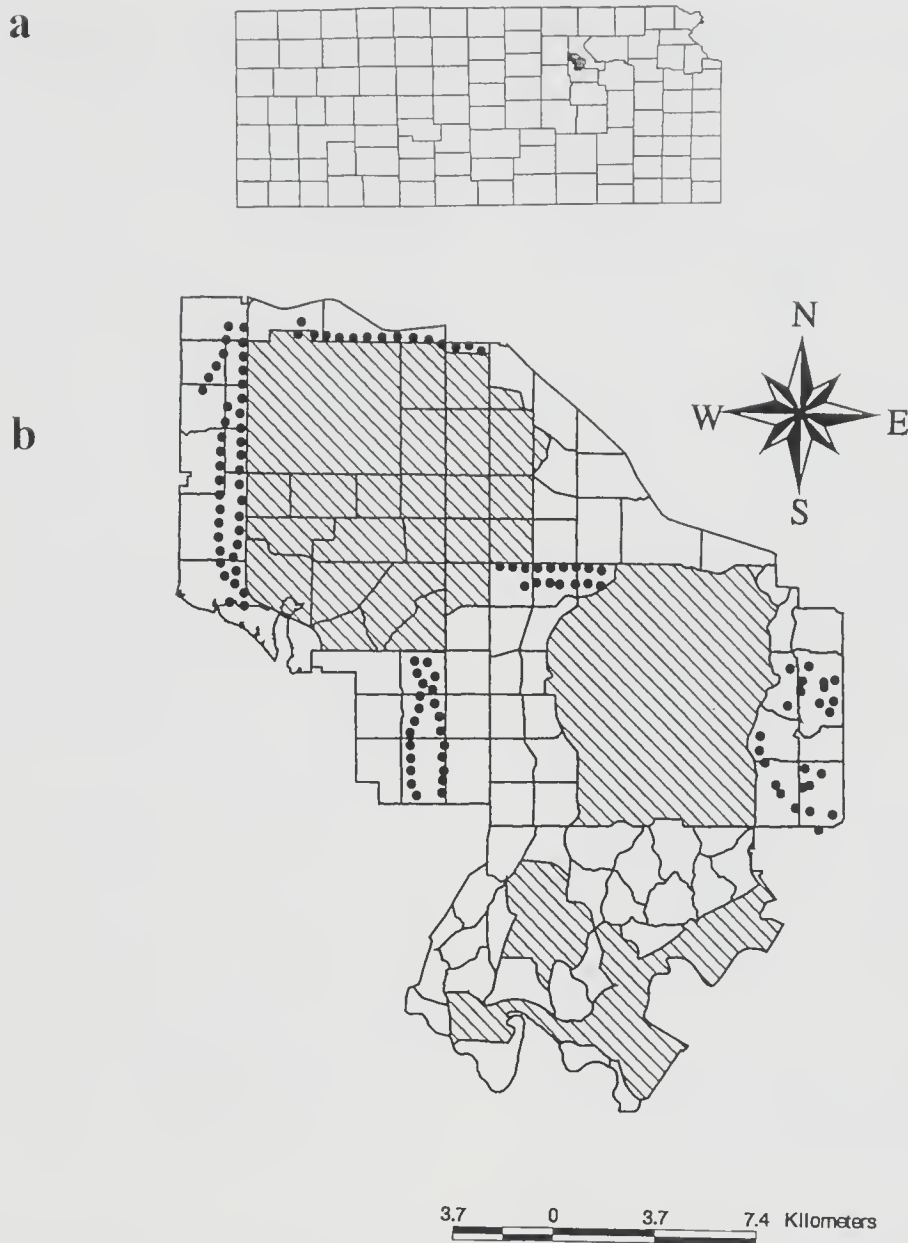


FIG. 1. Location of Fort Riley Military Reservation, Kansas, USA (A). Location of areas of restricted public access at Fort Riley Military Reservation, Kansas, USA (B). Access is limited in the Multipurpose Range Complex, shaded area in northwest, and is never available in the Impact Zone, the shaded area in the center of the fort. The shaded areas in the south are containment areas. We placed the census points (circles) in tallgrass prairie habitat where access was most available.

crease cover by perennial forbs (Anderson et al. 1970). Military disturbance has been shown to increase bare ground and cover by annual and warm season forbs (Johnson 1982, Shaw and Diersing 1990), contributing to an increase in structural heterogeneity.

This study was developed with three major objectives: (1) to determine the habitat associated with breeding Loggerhead Shrikes in tallgrass prairie at both the fine-scale (the scale of habitat within individual territories) and the landscape scale (the scale of the study area); (2) to determine if a relationship exists

between the intensity of military training disturbance to the vegetation and habitat associated with Loggerhead Shrikes; and (3) to provide recommendations for the proactive management of shrikes at Fort Riley Military Reservation.

#### STUDY AREA AND METHODS

Fort Riley, located in Riley and Geary counties in the Flint Hills of northeastern Kansas (Lat 39° 15' N, Long 97° 55' E; Fig. 1), is a 40,273 ha permanent U.S. Army Forces Command Reservation and is the site of ongoing military training. Training operations include field maneuvers, combat vehicle operations, mortar

and artillery fire, small arms fire, and aircraft flights (U.S. Army 1994). A 6480 ha Impact Area is off limits to maneuver training, public use, and most management activities at all times (Fig. 1). The Multipurpose Range Complex (MPRC) and the adjacent danger fan are closed to training and public use during live fire exercises. The remaining 4960 ha of training grounds that lie outside the MPRC and the danger fan are generally open throughout the year except during large scale training maneuvers held for several weeks in the spring and fall.

The Flint Hills extend from northeastern Kansas south to northeastern Oklahoma. Row crop agriculture is limited in the Flint Hills because of extensive limestone breaks and a shallow, rocky soil (Zimmerman 1985); most of the region is used as pasture. Landcover on Fort Riley includes native grassland and non-native planted grassland, open savannah, and wooded riparian lowlands (U.S. Army 1994). Pre-settlement grasslands in this region were comprised primarily of tallgrass prairie species interspersed in places with some mixed-grass prairie species (Kuchler 1974). Land uses and management prior to acquisition by the Army included agriculture, domestic livestock grazing, and fire suppression. Today, grasslands on Fort Riley experience varying levels of military disturbance. Mature riparian forest with shrubby edge occurs along lowland intermittent and perennial streams, and isolated patches of both trees and shrubs occur along intermittent drainages within the grasslands. Common woody species include rough-leaved dogwood (*Cornus drummondii*), plum (*Prunus americana*), smooth sumac (*Rhus glabra*), eastern red cedar (*Juniperus virginiana*), red mulberry (*Morus rubra*), osage orange (*Maclura pomifera*), and honey locust (*Gleditsia triacanthos*).

**Management history.**—Grazing is not permitted on Fort Riley; much of the area is hayed each year in conjunction with a hay lease program involving local landowners. Haying generally occurs in July on upland grassland sites that contain few trees and shrubs. Records are not kept as to which locations are hayed in a given year. Areas of the study site that were hayed during July 1995 and 1996 were recorded during this study.

Fort Riley's prescribed burn program operates from March through May (U.S. Army 1994). Approximately one-third of the Reservation is burned each year on a rotational basis, creating a planned burn interval of about three years for most areas. Training related wildfires occur throughout the year; consequently both the area burned and the frequency of burning in a given location can vary widely from year to year. The Fort Riley Natural Resources Office maintains records of all planned burns and most wildfires. This information was used to determine the burn history of the study area during the period 1992–1996.

**Bird surveys.**—In 1995, permanent bird survey points ( $n = 119$ ) were located at approximately 500 m intervals along transects 5–7 km in length. All survey points were placed outside of areas of restricted access such as the MPRC and the danger fan. Each survey

point was marked with flagged fence posts; Universal Transverse Mercator (UTM) coordinates were recorded using a Global Positioning System (GPS) unit.

From May–August, 1995, and from March–July, 1996, we made eight timed monthly surveys at each survey point using a modified variable circular-plot method (Reynolds et al. 1980) to locate breeding shrikes. The UTM coordinates of the specific location of each shrike use site was recorded. Each transect was surveyed beginning at first light and was completed by three hours after sunrise. Surveys were not conducted during heavy fog, rain, or when wind speeds exceeded 20 km/hr. In order to minimize sampling bias, the order in which transects were surveyed each month and the starting point and direction in which points were sampled along the transect were varied randomly. Because breeding shrikes were found to be relatively scarce on Fort Riley during the 1995 field season, in 1996 UTM coordinates were also recorded for birds found during the course of other field work. The date each bird was observed, the activity of the bird, and the type of perch being used (e.g., tree, shrub) when the bird was first located were recorded.

**Landscape scale habitat.**—For landscape scale analysis, the habitat within a 250 m radius of each survey point (a 19.6 ha plot) was identified, *a priori*, as either grassland ( $n = 35$ ), savannah ( $n = 44$ ), or woodland edge ( $n = 40$ ) according to the amount of cover by woody vegetation. The habitat class for a point was determined using a tree cover map developed by Kansas Biological Survey (KBS; Lauver et al. 1996) and on-site visual estimations. Grassland plots contained 15 or fewer isolated shrubs (<4 m in height) or trees (>4 m in height) or one copse 20 m in diameter. Savannah plots contained more than 15 shrubs or trees and did not contain continuous, wooded riparian habitat. Woodland edge points were located within 100 m of extensive, wooded riparian habitat that ran through the plot. The landscape habitat category of specific shrike locations (use sites) was determined using the same methods as for the survey points.

Use sites and survey sites were grouped into five burn treatments, based on the year the site was last burned, and two hay treatments, based on whether or not the site was hayed in 1995. A  $\chi^2$  analysis was conducted to determine if the observed frequencies of shrike use sites differed from a random distribution among the three habitat types, among the burn treatments, and among the hay treatments.

**Fine scale vegetative structure.**—Fine scale vegetation was sampled at use sites and survey sites during the spring and summer of 1996. Using a table of random digits, sampling plots were permanently located at a random distance (within 200 m) and direction from each survey point. Vegetation sampling plots were also centered around use sites in order to describe shrike fine-scale habitat. The density of shrubs (<4 m in height) and trees (>4 m in height) was measured within the sampling plot. Four meters height was selected because that was the minimum height a tree

could be detected using the remote sensing techniques employed by KBS (Lauver et al. 1996).

A point-intercept method was developed (modified from Rotenberry and Wiens 1980) to sample the structure of the herbaceous vegetation at 100 randomly located sampling points within the plot. At each of the 100 points within the plot, a 6 mm diameter rod marked in 10 cm intervals was dropped vertically through the vegetation. At each sampling point, the number of contacts of vegetation within each decimeter of the sampling rod was recorded according to the physiognomic class of the vegetation (live grasses, live forbs, standing dead vegetation). These samples were used to calculate measures of herbaceous vegetative cover and vertical and horizontal vegetative structure. Percent cover by each physiognomic class present at a site was calculated from the frequency of occurrence of each class at all 100 sampling points. Total vegetative cover was estimated as the proportion of points with at least one of the physiognomic classes of vegetation. Percent cover of litter was calculated as the proportion of sampling points with litter. When litter was present, its depth (cm) was measured and recorded. The maximum height of the vegetation contacting the rod at each sampling point was also recorded. The vertical density of the vegetation was calculated as the mean number of contacts of vegetation with the sampling rod. Two heterogeneity measures were calculated. The first was the coefficient of variation of the maximum height of the vegetation across the sampling plot. The second was the coefficient of variation of the vertical density of the vegetation across the sampling plot. Physiognomic cover diversity was calculated after Wiens and Rotenberry (1981) using Hill's (1973) reciprocal of Simpson's (1949) diversity index as

$$P = 1/\sum p_i^2,$$

where  $P$  is the physiognomic cover diversity index, and  $p_i$  is the proportional coverage of the  $i^{\text{th}}$  physiognomic class. This index indicates the equivalent to the number of physiognomic vegetation classes if all were equally abundant.

The severity of military disturbance to the vegetation was also identified at the fine scale. If vehicle tracks were intercepted by the sampling rod, the sampling point was given a score indicating the intensity of damage to the vegetation: 0 (no disturbance), 1 (crushed vegetation, little soil disturbance), 2 (extensive disruption of the soil, little remaining vegetation), or 3 (permanent gravel road). A military disturbance index was calculated for each site as the sum of the disturbance scores for all 100 sampling points within the plot.

*Principal components analysis.*—The spring 1996 fine-scale herbaceous vegetation data describing the bird survey points represent the range of values for the vegetative structure available to shrikes during the period of peak territory establishment (Tyler 1992). For this reason, these data were used as the baseline data for all comparisons. Because measures of vegetative

structure are highly correlated with one another (James 1971, Wiens and Rotenberry 1981), a principal components analysis (PCA) was conducted on the spring data to identify the patterns of covariation among the herbaceous vegetation variables. Principal components analysis has the advantage of reducing a large number of covarying variables to a smaller number of orthogonal components that maximize the variance accounted for in the data (Rotenberry and Wiens 1980, Gauch 1982). Habitat data from the shrike use site were applied to the early or late spring principal components to ordinate shrike use sites in the principal component space defined by the census points. By plotting shrike use site vegetation data in the principal component space defined by the spring survey point vegetation data, comparisons of the principal component scores using analysis of variance (ANOVA) could be made between use sites and survey sites in order to detect patterns of bird-habitat associations. Spring vegetation was sampled in early April and late May because a reservation-wide training exercise restricted access to the study site during late April and early May. A series of ANOVAs conducted on the principal component scores for sites sampled before and after the start of the growing season showed significant changes in each of the principal components, indicating that the date the data were collected may influence comparisons of vegetative structure among treatment groups. For this reason, the spring 1996 sampling period was treated as two separate sampling periods (early and late), and the principal component scores were grouped accordingly for further analysis.

All variables expressed as percentages were transformed using the arcsine square root transformation (Zar 1984) prior to analysis. Data are presented as mean ( $\bar{x}$ )  $\pm$  standard error (SE). Significance was established at  $P = 0.05$  for all comparisons.

The Shapiro-Wilk test (SAS Inst., Inc. 1992) was used to test the univariate assumption that the data are normally distributed, and Levene's test was used to test the univariate assumption that the treatment group variances were equal. For those comparisons for which the treatment variances were unequal, the SATTERTH option within the PROC MIXED procedure in SAS (SAS Inst., Inc. 1992) was employed to calculate appropriate degrees of freedom and fit the unequal variance model. If the Satterthwaite method did not change the results of the ANOVA, the test was assumed to be robust despite the heterogeneous variances, and the original data were retained. If, by fitting the unequal variance model, the results of the ANOVA changed, the test was conducted using the new degrees of freedom. Statistical analyses were performed using SAS (Version 6.11) software on an IBM compatible computer.

## RESULTS

*Landscape scale.*—Seven shrike use sites were located in 1995 and 12 use sites were located in 1996. All birds were observed dur-

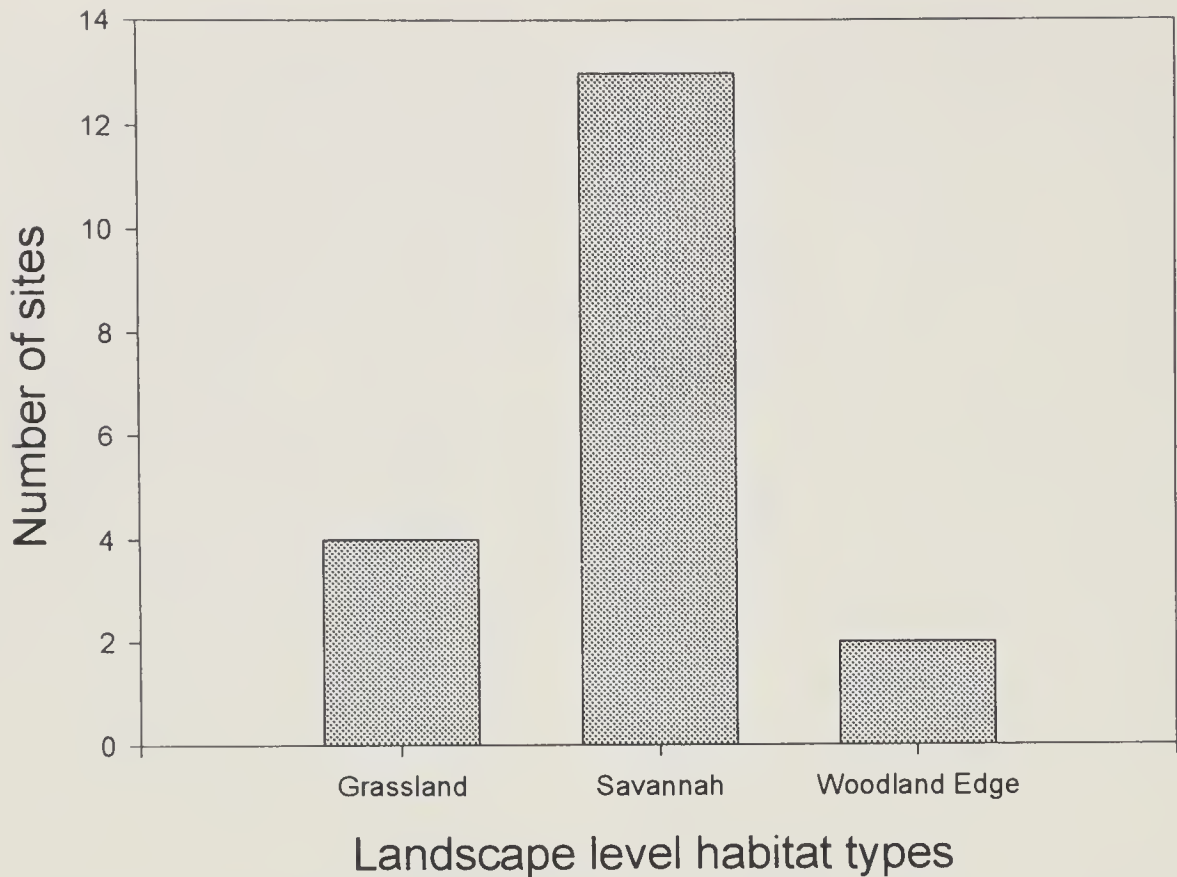


FIG. 2. Distribution of pooled 1995 and 1996 Loggerhead Shrike use sites ( $n = 19$ ) among landscape level habitat types, Fort Riley Military Reservation, Kansas ( $\chi^2 = 10.17$ , 2 df,  $P = 0.0062$ ).

ing the breeding season and were assumed to be independent breeding individuals based on territorial behavior and the large distance (usually  $>1$  km) between locations. Six of seven shrike observations in 1995, and 4 of 12 in 1996 were made at survey points. In 1995, we observed shrikes twice at one point on different surveys (counted as one bird), and in 1996, two birds were seen twice at the same point (also each counted as one bird). We located nests for two of the sightings in 1995 and six in 1996; thus we documented breeding for 8 of 19 birds by locating nests. Shrikes were most often observed foraging ( $n = 14$ ). Shrikes were significantly associated with savannah habitat at the landscape scale ( $\chi^2 = 10.17$ , 2 df,  $P = 0.0062$ ; Fig. 2).

Approximately 30% of the study area was hayed in 1995 (33 of 104 sites). In 1996, shrikes selected sites randomly with respect to hay treatment ( $n = 12$ ,  $\chi^2 = 0.05$ , 1 df,  $P > 0.05$ ). Four of the seven Loggerhead Shrike use sites located in 1995 were at sites burned two years earlier (in 1993). The other three use sites located in 1995 were burned three years before (in 1992). The majority of

shrikes located in 1996 ( $n = 12$ ) selected sites that were either burned in 1996 ( $n = 5$ ) or last burned in 1993 ( $n = 5$ ). This distribution was not significantly different from random with respect to the number of years since the site was last burned ( $\chi^2 = 4.45$ , 4 df,  $P > 0.05$ ).

*Fine scale.*—In 1996, vegetation sampling plots were centered on 12 Loggerhead Shrike use sites. Ten of the 12 sites were located and sampled during the early part of the spring sampling period and were therefore compared to early spring survey sites sampled before the middle of May ( $n = 54$ ).

The PCA of the spring 1996 fine-scale herbaceous vegetation data resulted in three principal components with eigenvalues greater than one (Table 1). Together, these components accounted for 84.0% of the total variance present in the data. High values of the first principal component (PC1) represent increasing total vegetative cover and vertical density, increasing cover by litter, and decreasing heterogeneity. High values of PC1 are representative of undisturbed tallgrass prairie, whereas low values of PC1 indicate high vertical and horizontal heterogeneity.

TABLE 1. Eigenvectors of fine scale vegetative variables for the first three principal components determined by a PCA of spring 1996 bird survey site herbaceous vegetation data. Values next to the habitat variables under PC1, PC2, and PC3 are factor loadings. Only loadings with values > |0.30| are included.

Variable	PC1	PC2	PC3
Eigenvalue	6.11	3.15	1.66
Variance explained	47%	24%	13%
Cumulative variance	47%	71%	84%
Cover			
Vegetation cover	0.393		
Standing dead cover		0.374	
Live grass cover		-0.358	
Live forb cover		-0.336	
Litter cover	0.302		
Physiognomic diversity			0.633
Vertical structure			
Litter depth		0.454	
Contacts in first decimeter		-0.401	
Total hits	0.381		
Maximum vegetation height		0.330	
Heterogeneity indices			
Horizontal heterogeneity	-0.379		
Vertical heterogeneity	-0.359		
Military disturbance			0.588

High values of the second principal component (PC2) represent increasing cover of standing dead vegetation, increasing maximum height of vegetation, increasing litter depth, and decreasing cover of live grass and live forbs, especially within 10 cm of the ground. Sites scoring highest on PC2 were those that had not been burned for three or more years, whereas sites with low PC2 scores generally were sites burned in 1996. High val-

ues of the third principal component (PC3) represent increasing physiognomic coverage diversity and increasing severity of military disturbance.

There was no significant difference at the fine-scale in the density of shrubs ( $F = 3.65, 1, 63 \text{ df}, P > 0.05$ ) or trees ( $F = 0.68, 1, 63 \text{ df}, P > 0.05$ ) among shrike use sites and survey sites (Table 2). The mean value of PC1 (vegetative cover and density, litter cover, and structural homogeneity) for shrike use sites was significantly lower than the mean value of PC1 for survey sites ( $F = 7.43, 1, 63 \text{ df}, P = 0.0083$ ), indicating selection of habitat with above average horizontal and vertical heterogeneity.

Levene's test was significant for heterogeneous variances of PC2 scores between shrike use sites and survey sites ( $P = 0.0439$ ). When the appropriate degrees of freedom were estimated (SATTERTH; SAS Inst., Inc. 1992), the initial results of the ANOVA changed, so the Satterthwaite estimates were retained (Table 2). Mean PC2 scores (litter depth, and height and cover by standing dead vegetation) for shrike use sites were significantly higher than those for the survey sites (Table 2). Mean PC3 scores (physiognomic cover diversity and disturbance index) did not differ between shrike use sites and survey sites ( $F = 0.14, 1, 65 \text{ df}, P > 0.05$ ; Table 2).

*Military track disturbance.*—No significant differences existed between Loggerhead Shrike use sites and survey sites with regard to military disturbance ( $F = 2.06, 1, 63 \text{ df}, P > 0.05$ ). The statistical power of this test was low (0.35) however, meaning that the failure to reject the null hypothesis when the alternative hypothesis is true is expected to occur with a 65% probability (Dallal 1988). This

TABLE 2. Loggerhead shrike use site means and site F-test *P*-values for early spring 1996 fine scale vegetative variables measured at Fort Riley Military Reservation, Kansas.

Vegetative variable	Early spring survey sites ( $n = 54$ )	Loggerhead Shrike use sites ( $n = 10$ )	<i>P</i> -value
Number of shrubs	10.98 ± 2.25	20.92 ± 4.69	>0.05
Number of trees	6.92 ± 1.61	10.00 ± 3.36	>0.05
Principal component 1	-1.37 ± 0.34	-3.52 ± 0.71	0.0083
Principal component 2	0.73 ± 0.28 <sup>a</sup>	2.19 ± 0.29 <sup>a</sup>	0.0010 <sup>b</sup>
Principal component 3	0.12 ± 0.19	0.28 ± 0.40	>0.05

<sup>a</sup> Unequal variance estimates.

<sup>b</sup> *P*-value is the result of using unequal variance estimates. Difference of LS Means = -1.46, and SE of the difference = 0.40.

means that it is inappropriate to use these results to argue that disturbance does not affect Loggerhead Shrikes. We merely have not shown that disturbance does affect them. This means that shrike use sites are typical, with respect to disturbance, of the rest of the grassland that we surveyed. The average survey point had a disturbance score of 35 ( $\pm 28.7$  SD, range 0–204), similar to our disturbance scores for the sites used by shrikes.

## DISCUSSION

The scale at which an ecological study is conducted is an important factor in the interpretation and understanding of the patterns observed (Forman 1995, Wiens et al. 1987, Wiens 1989). For example, the presence of several shrubsteppe bird species have been correlated with different vegetative characteristics at the regional and local scales of study (Wiens et al. 1987). We investigated Loggerhead Shrike habitat associations at both a landscape scale defined by macrohabitat types and at a finer scale within individual territories. Analysis at these two scales resulted in different patterns of woody vegetation associated with breeding locations used by shrikes.

At the landscape scale, shrikes at Fort Riley were associated with savannah habitat, suggesting that at this scale shrikes select sites in the tallgrass prairie with scattered woody vegetation. This pattern of selection is similar to that found for shrikes elsewhere in the United States. It supports the hypothesis that the availability of nesting sites is an important factor in habitat selection by breeding shrikes (Brooks and Temple 1990, Yosef and Grubb 1994).

At the fine-scale, shrike habitat at Fort Riley did not differ in either mean shrub density or mean tree density from random survey sites. Since the majority of the birds (70%) observed at use sites were foraging, these results suggest that the density of woody vegetation at the finer scale may be unimportant to foraging Loggerhead Shrikes. While the majority of shrikes in this study were first seen perched on woody vegetation, this may be because they are more easily seen perched at these heights. During further observation, birds were often seen perched on prairie grasses and forbs ranging in height from 0.5–2 m. In contrast to homogeneous pastureland, the

structural heterogeneity of tallgrass prairie provides shrikes with perching and foraging substrates other than offered by woody vegetation (Chavez-Ramirez et al. 1994).

The importance of vegetative structural heterogeneity to shrikes is shown by the fact that shrikes used sites at Fort Riley that had significantly greater structural heterogeneity (low values of PC1) than did random sites. Shrikes also used sites with lower total vegetative cover, lower litter cover, and more bare ground (low values of PC1); taller vegetation, standing dead vegetation, and deeper litter (high values of PC2) than random sites. These results suggest that structurally heterogeneous native prairie that has tall vegetation interspersed with areas of bare ground may provide shrikes with adequate foraging habitat at the fine-scale.

Shrikes used sites with high structural heterogeneity despite the fact that they did not differ from random with respect to burn history, haying the year before, or the military vehicle track disturbance index. We predicted that shrikes would be associated with high vegetative structural heterogeneity, and that the heterogeneity would be associated with greater military vehicle track disturbance. It is reasonable to expect that even moderate levels of military vehicle track disturbance to the vegetation are capable of creating the structurally heterogeneous ground cover selected by shrikes at Fort Riley.

It is possible that vehicular disturbance to the vegetation may help sustain scattered woody vegetation at the landscape scale for breeding shrikes. Military vehicle activity, crushing vegetation, creating bare patches, and soil compaction, may have indirect effects on the vegetation at Fort Riley because of interactions with hay harvest and fire. For example, at Konza Prairie Research Natural Area, a Long Term Ecological Research site, annual and 2-yr burn intervals in watersheds without vehicle track disturbance eliminate woody vegetation and most forbs, yielding a structurally simple plant cover of mostly warm-season grasses without vertical and horizontal habitat variability like that at Fort Riley. Despite the burning of most areas of Fort Riley every 2–4 years, many scattered, isolated trees and hedgerows exist at the landscape scale and represent potential nesting

habitat for Loggerhead Shrikes (Lauver et al. 1996). By fragmenting patches of herbaceous vegetation and reducing soil drainage through compacting, vehicular disturbance may indirectly reduce the intensity of fire in localized areas, thus reducing the fire-caused destruction of established woody vegetation.

The results from this study show that shrikes at Fort Riley are associated with scattered trees and shrubs at the landscape scale and with structurally heterogeneous herbaceous vegetation at the fine-scale. Military training may have both short and long term roles in maintaining shrike habitat at both scales. In order to better understand the relationship between training and habitat conditions, the long term effects of training disturbance to shrike habitat at Fort Riley need to be studied.

ACKNOWLEDGEMENTS

Research amidst active training at a military installation is an exciting if often challenging experience. We wish to thank H. J. Able, K. A. Cherry, C. K. Jeffrey, D. P. Jones, J. Keating, B. C. Philips, and M. M. Ponte of the Fort Riley Natural Resources Division for their logistical help and encouragement at Fort Riley. G. A. Hoch and R. S. Matlack helped establish the survey sites, and P. Lemons helped collect large volumes of vegetation data. We also thank W. H. Busby, C. L. Lauver, P. S. Gipson, G. A. Milliken, R. Yosef, J. L. Zimmerman and an anonymous reviewer for their thoughtful comments on the manuscript. Funding support for this project was provided by the U.S. Army.

LITERATURE CITED

ANDERSON, K. L., C. E. OWENSBY, AND E. F. SMITH. 1970. Burning bluestem range. *J. Range Manage.* 23:81-92.  
 ARBIB, R. 1976. The blue list for 1977. *Am. Birds* 30: 1031-1039.  
 ARBIB, R. 1977. The blue list for 1978. *Am. Birds* 31: 1087-1096.  
 ARBIB, R. 1978. The blue list for 1979. *Am. Birds* 32: 1106-1113.  
 ARBIB, R. 1979. The blue list for 1980. *Am. Birds* 33: 830-835.  
 BOHALL-WOOD, P. 1987. Abundance, habitat use, and perch use of Loggerhead Shrikes. *Auk* 94:28-35.  
 BROOKS, B. L. AND S. A. TEMPLE. 1990. Habitat availability and suitability for Loggerhead Shrikes in the upper Midwest. *Am. Midl. Nat.* 123:75-83.  
 CADE, T. J. AND C. P. WOODS. 1997. Changes in distribution and abundance of the Loggerhead Shrike. *Conserv. Biol.* 11: 21-31.  
 CHAVEZ-RAMIREZ, F., D. E. GAWLIK, F. G. PRIETO, AND R. D. SLACK. 1994. Effects of habitat structure on

patch use by Loggerhead Shrikes wintering in a natural grassland. *Condor* 96:228-231.  
 DALLAL, G. E. 1988. Design: a supplementary module for SYSTAT and SYSGRAPH. SYSTAT Inc. Evanston, Illinois.  
 FORMAN, R. T. T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge Univ. Press, Cambridge, U.K.  
 GAUCH, H. G., JR. 1982. Multivariate analysis in community ecology. Cambridge Univ. Press, Cambridge, U.K.  
 GIBSON, D. J. 1989. Hulbert's study of factors affecting botanical composition of tallgrass prairie. *Proc. N. Am. Prairie Conf.* 11:115-133.  
 HILL, M. O. 1973. Diversity and evenness: a unifying notation and its consequences. *Ecology* 54:427-432.  
 JAMES, F. 1971. Ordinations of habitat relationships among breeding birds. *Wilson Bull.* 83:215-236.  
 JOHNSON, F. L. 1982. Effects of tank training activities on botanical features at Fort Hood, Texas. *Southwest. Nat.* 27:309-314.  
 KRIDELBAUGH, A. L. 1981. Population trend, breeding and wintering distribution of Loggerhead Shrikes (*Lanius ludovicianus*) in Missouri. *Trans. Mo. Acad. Sci.* 15:111-119.  
 KUCHLER, A. W. 1974. A new vegetation map of Kansas. *Ecology* 55:586-604.  
 LAUVER, C. L., W. H. BUSBY, K. KINDSCHER, AND J. L. WHISTLER. 1996. Identification and delineation of Loggerhead Shrike habitat on the Fort Riley Military Reservation. *Kans. Biol. Surv. Rep.* 69:1-33.  
 MORRISON, M. L. 1981. Population trends of the Loggerhead Shrike in the United States: a statistical study of Christmas Bird Count reports provides qualified confirmation of the species' Blue-listing. *Am. Birds* 35:754-757.  
 PRESCOTT, D. R. C. AND D. M. COLLISTER. 1993. Characteristics of occupied and unoccupied Loggerhead Shrike territories in southeastern Alberta. *J. Wildl. Manage.* 57:346-352.  
 REYNOLDS, R. T., J. M. SCOTT, AND R. A. NUSSBAUM. 1980. A variable circular-plot method for estimating bird numbers. *Condor* 82:309-313.  
 ROTENBERRY, J. T. AND J. A. WIENS. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. *Ecology* 61:1228-1250.  
 SAS INSTITUTE, INC. 1992. Changes and enhancements, release 6.03 edition. SAS/STAT Technical Report P-229, Cary, North Carolina.  
 SHAW, R. B. AND V. E. DIERSING. 1990. Tracked vehicle impacts on vegetation at the Piñon Canyon Maneuver Site, Colorado. *J. Environ. Qual.* 19:234-243.  
 SIMPSON, E. H. 1949. Measurement of diversity. *Nature* 163:688.  
 SMITH, E. J. AND K. C. KRUSE. 1992. The relationship between land-use and the distribution and abun-



- dance of Loggerhead Shrikes in south-central Illinois. *J. Field Ornith.* 63:420–427.
- TELFER, E. S. 1992. Habitat change as a factor in the decline of the western Canadian Loggerhead Shrike, *Lanius ludovicianus*, population. *Can. Field Nat.* 106:321–326.
- TYLER, J. D. 1992. Nesting ecology of the Loggerhead Shrike in southwestern Oklahoma. *Wilson Bull.* 104:95–104.
- U.S. ARMY. 1994. Integrated natural resource management plan for Fort Riley, Kansas. Prepared by L. Berger and Associates, Inc. for the Directorate of Engineering and Housing, Environmental and Natural Resources Division, Ft. Riley, Kansas.
- WIENS, J. A. 1989. *The ecology of bird communities*. Cambridge Univ. Press, Cambridge, U.K.
- WIENS, J. A. AND J. T. ROTENBERRY. 1981. Habitat associations and community structure of birds in shrubsteppe environments. *Ecol. Monogr.* 5:21–41.
- WIENS, J. A., J. T. ROTENBERRY, AND B. VANHORNE. 1987. Habitat occupancy patterns of North American shrubsteppe birds: the effects of spatial scale. *Oikos* 48:132–147.
- YOSEF, R. AND T. C. GRUBB, JR. 1993. Effect of vegetation height on hunting behavior and diet of Loggerhead Shrikes. *Condor* 95:127–131.
- YOSEF, R. AND T. C. GRUBB, JR. 1994. Resource dependence and territory size in Loggerhead Shrikes (*Lanius ludovicianus*). *Auk* 111:465–469.
- ZAR, J. H. 1984. *Biostatistical analysis*. Second ed. Prentice Hall, Englewood Cliffs, New Jersey.
- ZIMMERMAN, J. L. 1985. The birds of Konza Prairie Research Natural Area, Kansas. *Prairie Nat.* 17:185–192.